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A RADIOWAVE PROPAGATION
DATA ACQUISITION SYSTEM

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Hardware and software for a computer controlled radiowave propagation data acquisition system is described.

SUMMARY

This report describes the hardware and software for implementation of a computer controlled system for the acquisition of radiowave propagation data. The system consists of an instrumentation receiver, a digital voltmeter to sample the detected IF output of the receiver, a digital clock, and a controller.

Using the software described herein the system samples the received signal about seven times per second. The data samples are processed to provide hourly values of the average and median signal power levels and the number of fades of depth 10 db, 15 db, 20 db, 25 db and 30 db below the median signal level for the previous hour. The cumulative distribution of signal power level is determined for each day. Average duration of a fade of specified depth may be calculated from the above information.

Processed data are stored in tape files. As currently configured the system will store data for an entire month. Tapes may be removed and replaced periodically to obtain a permanent record.

The system has the capability to start up automatically after a power failure.

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I. INTRODUCTION

A. Background

In any radiowave communication system the signal is modified to some extent by the channel through which it propagates as it travels from transmitter to receiver. A time harmonic signal is completely defined by its amplitude and angle. Generally the magnitude or the angle of an RF carrier is modulated at the transmitter in accordance with the information to be transmitted. However, the channel causes further variations in amplitude and angle and these variations often impair the ability of the communication receiver to extract the desired information from the received signal.

Signal fluctuations caused by the propagation channel vary with time. The nature of the fluctuation is predictable only in a qualitative sense. Quantitatively the fluctuations are only predictable on a statistical basis. It is known, for example, that the attenuation of a skywave signal propagating through the ionosphere will exhibit a diurnal variation. The average attenuation may be predicted but the actual value at any given time is subject to solar activity. The time at which the attenuation might depart from the average and the extent of the change are not predictable deterministically since it is not possible to predict solar disturbances. Similarly, signals propagating through the troposphere will be altered by unpredictable changes in the index of refraction of the earth's lower atmosphere.

A practical implication of channel induced signal fluctuations is that the signal amplitude will vary and may be reduced to the point where the S/N is no longer adequate for satisfactory communication. It is possible to overcome this degradation to some extent by such techniques as increasing transmitter power, signal coding and diversity but even these approaches cannot completely eliminate the problem. One can only approach the system problem on a probabilistic basis and design for satisfactory performance a specified fraction of the time. It is therefore imperative that the channel statistics be known.

Over the years the characteristics of various communication channels have been studied and modeled both analytically and numerically. Without exception the models have been developed and fit to experimental observations. Although much data has been published it is still often necessary to make experimental measurements. Measurement equipment has been developed by various organizations in response to their needs but still it is generally necessary to devise one's own system if measurements are to be made.

B. Problem

For the reasons mentioned previously the Naval Undersea Weapons Engineering Station (NUWES) has an interest in defining the characteristics of certain tropospheric channels in the Pacific Northwest of the USA. The specific problem which this report addresses is the development of a Radiowave Propagation Data Acquisition System. Although developed for use at NUWES the system has been configured using off the shelf instruments and should be adaptable to a wide range of similar applications either directly or with only very minor changes.

The system samples detected RF signal amplitude at the rate of approximately 7 samples/second. For each hour average signal power, median signal power and number of fades of depth 10 db - 30 db in 5 db increments (relative to the median for the previous hour) is determined. The cumulative distribution of signal power is also determined on a daily basis. The average duration of a fade of a given depth may be calculated (see Sec. IV).

II. SYSTEM HARDWARE

A Radiowave Propagation Data Acquisition System providing the capability described in Sec. IB was configured using commercially available hardware. The system block diagram is shown in Figure 1 and it can be seen that it consists of a Sensor Subsystem and a Data Acquisition and Processing Subsystem.

The Sensor Subsystem contains an antenna appropriate to the frequency range and application, a preamplifier, a microwave receiver and a detector.

The preamplified signal is applied to the input of the SA1710 receiver. The frequency coverage of this receiver is 20 MHz to 40 GHz. This frequency range is covered using various mixers and converters for the different RF bands. The 10 MHz IF output of the receiver is detected to provide a measure of the RF input signal strength. The signal may be detected using a bolometer, a thermistor (power meter) or a crystal detector. A crystal detector was chosen for the present application since its fast response time permits it to follow the short, deep fades which are to be expected.

The receiver must be calibrated for each band. The SA1720B low frequency converter is used to cover the 20 MHz to 940 MHz band. Figure 2 shows the calibration curve obtained using the SA1720B and a HP8742A detector. An RF input frequency of 265 MHz was used for the calibration. It is evident the response is linear to within ±1 db for RF inputs between -20 dbm and -50 dbm providing a 30 db

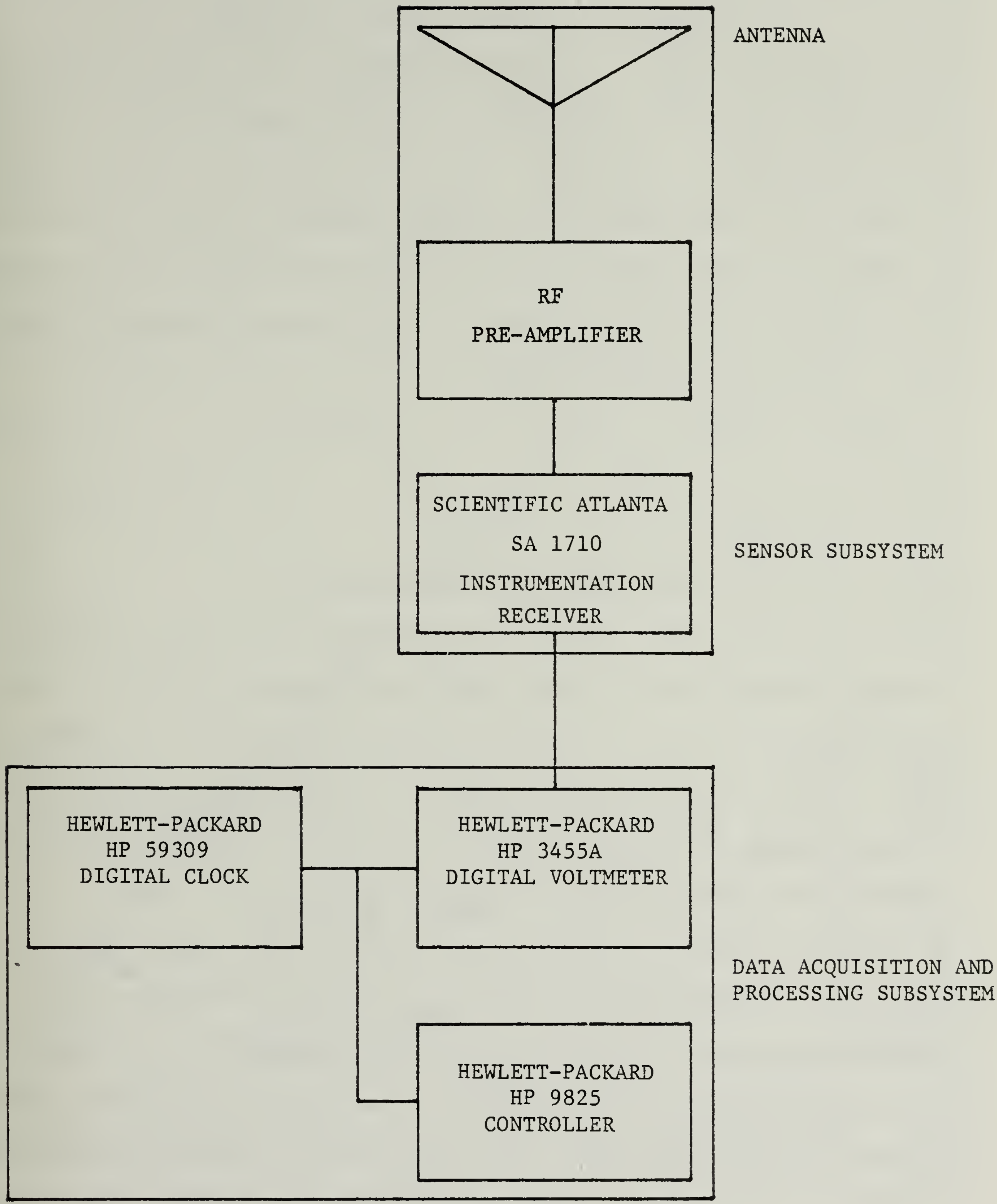

FIGURE 1. Radiowave Propagation Data Acquisition System Block Diagram

linear dynamic range. This was obtained with 18 db of receiver IF attenuation and thus the linear dynamic range may be shifted up to 18 db lower by decreasing the IF attenuation. With no IF attenuation, for example, the linear dynamic range becomes -38 dbm to -68 dbm. The dynamic range may be easily extended to 45 db by fitting a third order curve to the measured response. By point matching one may obtain

$$B = 1.025I - 4 + .000577\,(I + 31)^3 \qquad (1)$$

where

B = RF input power in dbm

I = 20 log (|detected IF voltage|)

Figure 2 shows this curve is accurate to ± 1/2 db. An instantaneou dynamic range of 45 db was considered adequate for the present application. This permits the median signal to be amplified so as to produce a "Q point" roughly 5-10 db below the top of the dynamic range which allows fades of 30 db to be seen with a minimum of 5 db of dynamic range to spare.

The RF preamplifier must provide an input signal to the receive which is at the proper level within the dynamic range. The required gain and noise figure of this amplifier will depend upon the user's application. A good low noise, high gain amplifier should almost always meet the requirements when used along with variable attenuation. Care must be taken to assure that the signal will lie within the dynamic range of the preamplifier, however. Attenuation may be required at the preamplifier input to achieve this if the input signal level is too high.

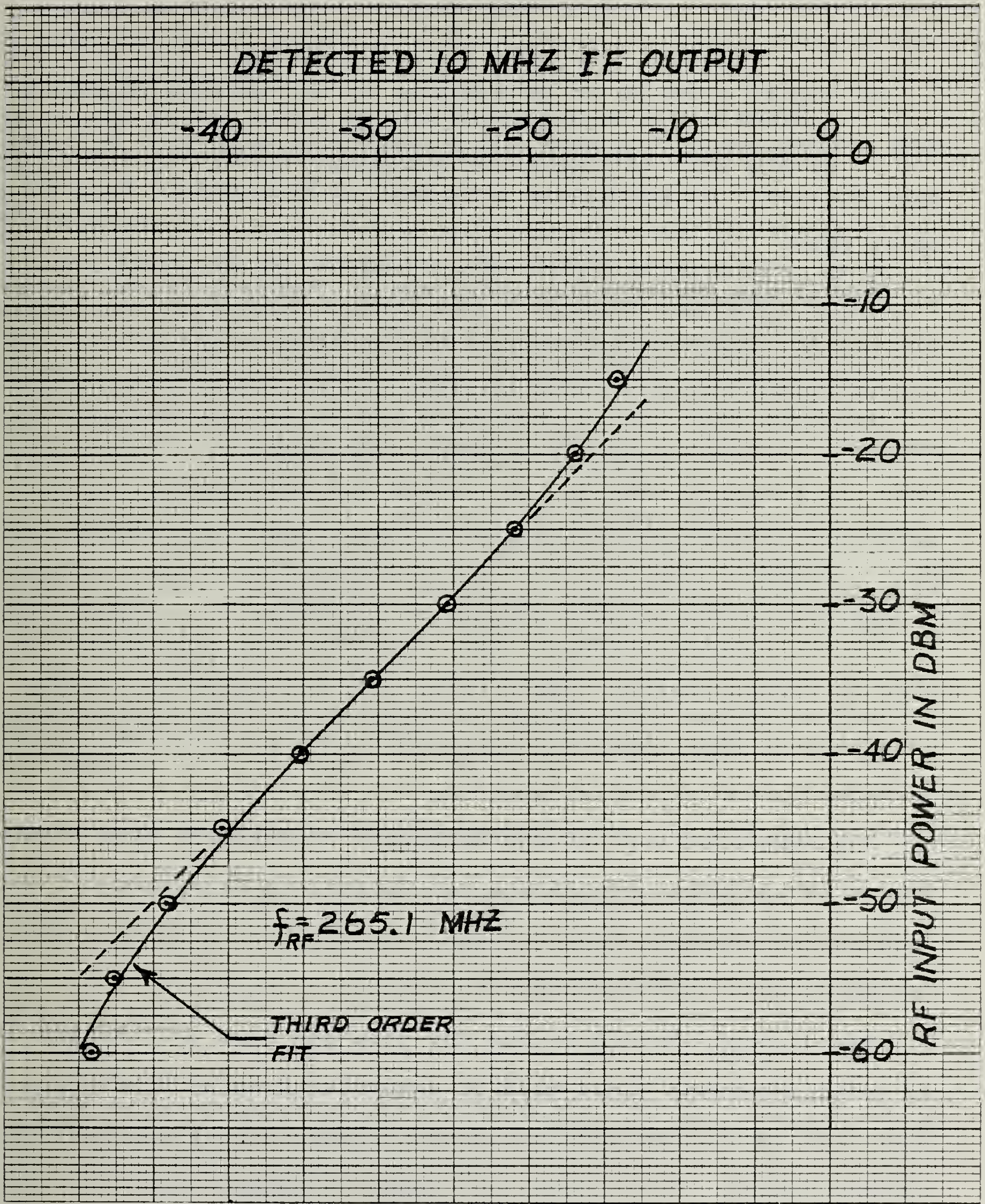

FIGURE 2. Sensor Subsystem Calibration Curve

If signal power is to be computed at the antenna terminals then transmission line loss and preamplifier gain must be taken into account. An additional term must be included in Equation (1) to do this.

Use of the Sensor Subsystem shown in Figure 1 is not necessary. If another receiver is available with a detected IF output this may be used in place of the SA1710. For example, it might be possible to utilize an AGC voltage. The only requirements are that the response time be fast enough and the dynamic range be adequate. If these requirements are met, then the receiver may be calibrated and used in the Sensor Subsystem. A curve must be fit to the receiver response and an appropriate change must be made in the subroutine "samp" (Sec. III, Software) at line 50 where the RF input power is calculated from the detected output voltage.

The remaining part of the Radiowave Propagation Data Acquisitio System is the Data Acquisition and Processing Subsystem. This contains the Hewlett Packard HP9825 controller, a HP3455A digital voltmeter and a HP59309 digital clock.

The digital clock provides the date and time for the system. T is quite important since data is accumulated on an hourly and daily basis and it is therefore necessary to know when a new hour or a new day begins. The digital voltmeter is a high accuracy, high resolution unit which is used to sample the detected IF signal voltage. The samples are taken upon receipt of a trigger command from the controller. The DVM is also function programmable and is set to the proper state at the beginning of the program. Thereafter it is left unchanged functionally. The DVM is autoranging.

The heart of the System is the HP9825 controller. It is configured with the following ROMs: General I/O, Extended I/O, String and Advanced Programming. All of these are necessary for execution of the program described in Sec. III, Software. Only the basic 8K memory is required, however.

The controller loops continuously through the control program. Samples are taken at the rate of about 7 samples/second. These samples are processed to develop the desired statistics and all information is stored on tape at the end of each day. The functioning of the program is described in detail in the next section.

III. SYSTEM SOFTWARE

A. General Program Description

The flow chart for the system program is shown in Figure 3. It consists of two main parts; the first four blocks which are traversed only when the program is started and the remaining blocks which form a continuous loop.

In the first part of the program the necessary array variables are dimensioned, the DVM is set to the proper state, the date and time of program startup is printed and the signal power level at the startup time is printed. This power is used as a reference for detecting fades for the remainder of the first hour of operation.

The continuous loop starts at point 1 in Figure 3. First, the previous clock reading and the previous signal power sample value are moved from the current value locations in memory (A$ and A respectively) to the past value locations in memory (B$ and B respectively). Next the clock is read and the time is tested to determine if a new hour has begun.

If no new hour has begun the receiver output is sampled and the input signal power level is computed. The time in hours and the input signal power level in dbm are then displayed. Next the current sample signal power in milliwatts is added to the sum of the power for previous samples for later computation of the hourly average signal power. Following this the number (of samples

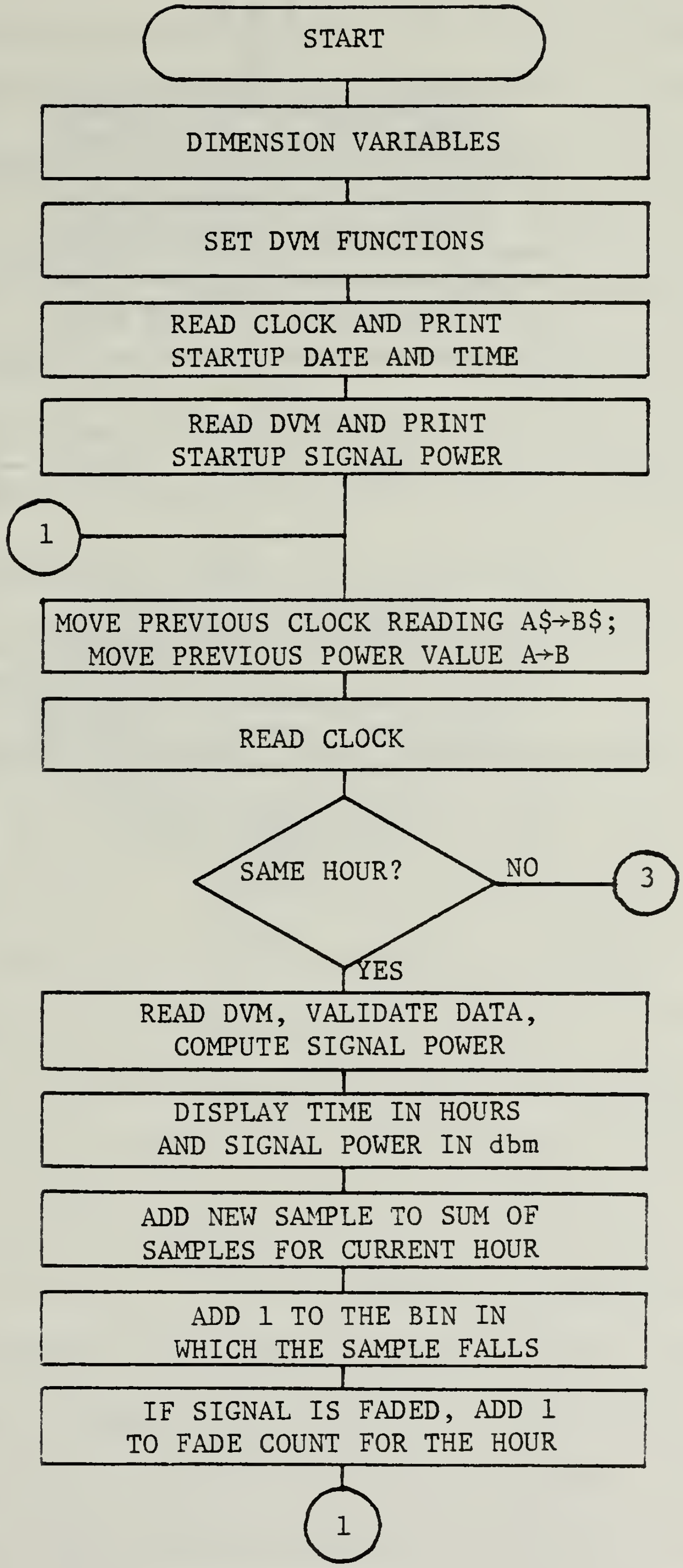

FIGURE 3. System Program Flow Diagram

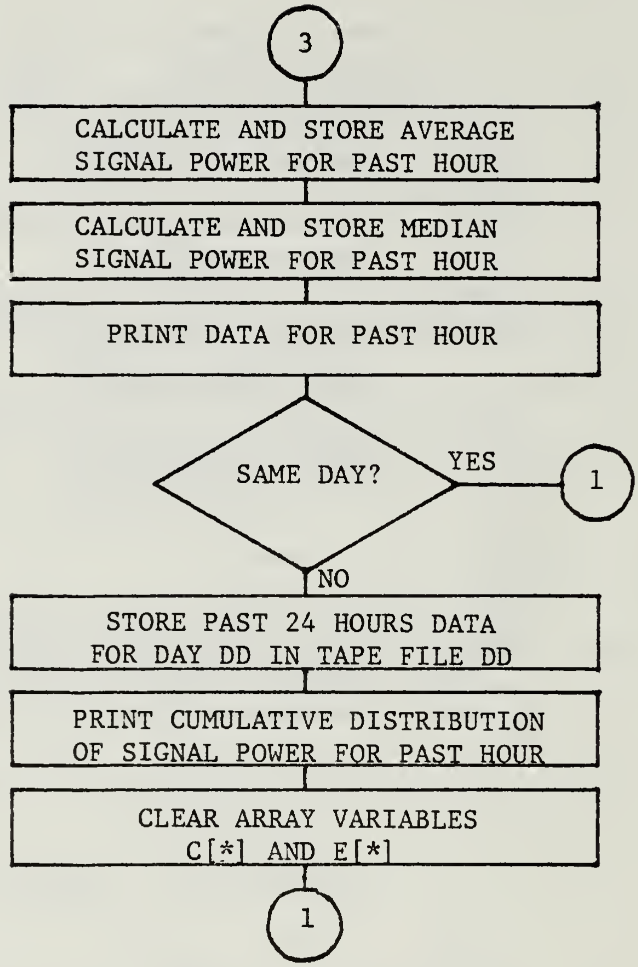

FIGURE 3. System Program Flow Diagram (Continued)

in the bin in which the signal power falls is incremented by 1. Bins are numbered -45 to -90 in steps of -1. A reading of -53.2 dbm would cause bin -54 to be incremented by 1 count (int (-53.2) = -54). Finally, the current and past power samples are checked to detect negative slope threshold crossings (fades) relative to the median signal power for the previous hour. Thresholds are set at 5 db increments from -10 db to -30 db. If a threshold crossing is detected, then it is counted by incrementing the count for that threshold level and that hour by 1. Each threshold is tested every time a sample is taken. Execution continues at point 1 in Figure 3.

If a new hour has started, the program branches to point 3 in Figure 3. At this point the average signal power for the past hour is calculated by dividing the power sum for all (valid) samples by the number of (valid) samples. Sample validation will be discussed later. Similarly, the median signal power for the past hour is also computed. Data for the past hour is then printed. This printout may be suppressed as will be explained shortly.

The hourly printout lists the number of valid samples, the number of bad samples, the average signal power, the median signal power and the number of fades of depth 10 db, 15 db, 20 db, 25 db and 30 db if such fades occurred. A sample printout is shown in Figure 6 which is discussed in Section IV.

At the beginning of each new hour a test is made to determine if a new day has begun. If a new day has not begun then execution continues at point 1 in Figure 3. If a new day has begun then all data for the 24 hour period which has just ended is stored on tape. The storage location is track 0, file DD where DD is the date. Files are thus filled from the first day of the month until the end of the month after which time old files will be written over as new files are stored. The files contain the variables B$, C[*] and E[*]. The information contained in the elements of these variables will be explained shortly.

After storing the array variables C[*] and E[*] on tape these variables are initialized to zero for accumulation of data during the new day. Execution then continues at point 1 in Figure 3.

B. Detailed Program Description

A complete listing of the system program appears in Figure 4. Figure 5 is the output obtained from execution of the xref statement (Advanced Programming ROM) and lists all variables used in the program and the lines in which they appear. A discussion of each part of the program follows.

1. Bootstrap.

Lines 0 through 17 constitute a bootstrap routine. If the program is stored on track 0 in file 0 it will automatically be loaded and run when the HP9825 is powered on. This is a useful feature if the system is unattended and power failures are anticipated. The user should incorporate a loop with a wait

```
0: gsb "dim"
1: on err "rcvr"
2: rem 722
3: llo 7
4: wrt 722,"T2"
5: "STARTUP ON
  /   "→C$
6: red 708,A$
7: if num(A$[2])
 #32;jmp -1
8: A$[3,4]→C$[12
 ,13]
9: A$[5,6]→C$[15
 ,16]
10: prt C$
11: "AT
 HOURS    "→C$
12: A$[7,10]→C$[
 4,7]
13: prt C$
14: gsb "samp"
15: A→E
16: prt "START
 dbm",E
17: spc 3
18: "1":A$→B$;
 A→B
19: red 708,A$
20: if num(A$[2]
 )#32;Z+1→Z;jmp
 -1
21: if val(A$[7,
 8])=val(B$[7,
 8]);gto "2"
22: gto "3"
23: "2":gsb "sam
 p"
24: fxd 2;dsp
 A$[7,10]," HOUR
 S","    SIG ",A,
 "   dbm
25: gsb "sum"
26: gsb "bin"
27: gsb "fade"
28: gto "1"
29: "3":gsb "avg
 "
30: gsb "med"
31: gsb "hrly
 prt"
32: if val(A$[5,
 6])=val(B$[5,
 6]);gto "1"
33: gsb "tsto"
34: gsb "dly
 prt"
35: spc 1
36: gsb "clr
 C[]"
37: gto "1"
38: "dim":dim
 B$[12]
39: dim C[9,0:23
 ]
40: dim E[-90:-
 45]
41: dim A[-90:-
 45]
42: dim A$[12]
43: dim C$[16]
44: ret
45: "samp":rem
 722
46: trg 722
47: red 722,A
48: if A=0;val(A
 $[7,8])→D;C[2,
 D]+1→C[2,D];
 jmp -3
49: 10log(abs(A)
 )→A
50: 1.025*A-25+
 .000577*(A+31)↑
 3→A
51: if A>-45;
 val(A$[7,8])→D;
 C[2,D]+1→C[2,
 D];dsp A;jmp -6
52: if A<-90;
 val(A$[7,8])→D;
 C[2,D]+1→C[2,
 D];dsp A;jmp -7
53: ret
54: "sum":val(A$
 [7,8])→D
55: C[3,D]+10↑(A
 /10)→C[3,D]
56: C[1,D]+1→C[1
 ,D]
57: ret
58: "bin":int(A)
 →D
59: A[D]+1→A[D]
60: ret
61: "fade":val(A
 $[7,8])→D
```

FIGURE 4. System Program Listing

```
62: if A<E-10
 and E-10<B;C[5,
 0]+1→C[5,0]
63: if A<E-15
 and E-15<B;C[6,
 0]+1→C[6,0]
64: if A<E-20
 and E-20<B;C[7,
 0]+1→C[7,0]
65: if A<E-25
 and E-25<B;C[8,
 0]+1→C[8,0]
66: if A<E-30
 and E-30<B;C[9,
 0]+1→C[9,0]
67: ret
68: "avg":val(B$
 [7,8])→D
69: if C[1,0]=0;
 jmp 2
70: 10log(C[3,
 0]/C[1,0])→C[3,
 0]
71: ret
72: "med":0→D
73: C[1,val(B$[7
 ,8])]/2→C
74: for I=-45
 to -90 by -1
75: A[I]+E[I]→E[
 I]
76: A[I]+D→D
77: 0→A[I]
78: if D>C;I→C[4
 ,val(B$[7,8])];
 -30000→D;I→E
79: next I
80: ret
81: "hrly prt":B
 $[7,8]→C$[1,2]
82: " HOURS
     "→C$[3,16]
83: prt C$
84: val(B$[7,
 8])→D
85: fxd 0
86: prt "# valid
 [illegible],C]
87: prt "# [illegible]
 C[2,0]
88: if C[1,0]=0;
 jmp 8
89: fxd 2;prt
 "avg dbm",C[3,
 0]
90: fxd 0;prt
 "med dbm",C[4,
 0]
91: if C[5,0]>0;
 prt "#10db fade
 s",C[5,0]
92: if C[6,0]>0;
 prt "#15db fade
 s",C[6,0]
93: if C[7,0]>0;
 prt "#20db fade
 s",C[7,0]
94: if C[8,0]>0;
 prt "#25db fade
 s",C[8,0]
95: if C[9,0]>0;
 prt "#30db fade
 s",C[9,0]
96: if Z>0;prt
 "clk errors",Z;
 0→Z
97: spc
98: ret
99: "clr C[]":fo
 r I=0 to 23
100: 0→C[1,I];
 0→C[2,I];0→C[3,
 I];0→C[4,I]
101: 0→C[5,I];
 0→C[6,I];0→C[7,
 I];0→C[8,I];
 0→C[9,I]
102: next I
103: for I=-90
 to -45
104: 0→E[I]
105: next I
106: ret
107: "-sto":trk
 0
108: [illegible] 1,B$[5,
 6])→D
109: rcf D,B$,
 C[*],E[*]
110: ret
111: 'dly prt":
 SIG DSITRIBUT
 N"→C$
112: prt C$
113: spc
114: "SIG PWR
 #SAMPLES"→C$
115: prt C$
116: spc
117: for I=-45
 to -90 by -1
118: fxd 0;str
 )→C$[1,3];"
 dbm "→C$[4,8]
 str(E[I])→C$[
 16]
119: prt C$
120: next I
121: spc 2
122: "DAY     /
        "→C$
123: A$[3,4]→C$
 5,6]
124: A$[5,6]→C$
 8,9]
125: prt C$
126: spc
127: ret
128: "rcvr":cl
 7
129: prt "rom",
 rom
130: prt "error
 ,ern
131: prt "line"
 erl
132: spc 1;gto
*17786
```

FIGURE 4. System Program Listing
(Continued)

```
A    15   18   24
47   48   49   49
50   50   50   51
51   52   52   55
58   62   63   64
65   66

B    18   62   63
64   65   66

C    73   78

D    48   48   48
51   51   51   52
52   52   54   55
55   56   56   58
59   59   61   62
62   63   63   64
64   65   65   66
66   68   69   70
70   70   72   76
76   78   78   84
86   87   88   89
90   91   91   92
92   93   93   94
94   95   95   108
109

E    15   16   62
62   63   63   64
64   65   65   66
66   78

I    74   75   75
75   76   77   78
78   79   99   100
100  100  100  101
101  101  101  101
102  103  104  105
117  119  118  120
```

```
[illegible]    0    [illegible]    96
96   96

A[*]41   59   59
75   76   77

C[*]39   48   48
51   51   52   52
55   55   56   56
62   62   63   63
64   64   65   65
66   66   69   70
70   70   73   78
86   87   88   89
90   91   91   92
92   93   93   94
94   95   95   100
100  100  100  101
101  101  101  101
109

E[*]40   75   75
104  109  118

A$   6    7    8
9    12   18   19
20   21   24   32
42   48   51   52
54   61   123  124

B$   18   21   32
38   68   73   78
81   84   108  109

C$   5    8    9
10   11   12   13
43   81   82   83
111  112  114  115
118  118  118  119
122  123  124  125
```

FIGURE 5. System Program Variable Listing

statement in the bootstrap, however, to allow for warmup and stabilization of instruments before data taking is initiated. Bootstrap operation is as described in the previous discussion of the flow diagram (Sec. IIIA).

2. Main Program

The main program is contained in lines 18 through 37. The reader should be able to correlate the statements with the various blocks of the flow chart in Figure 3. Basic program operation is as described in Section IIIA. The various subroutines called by the main program will now be discussed in some detail.

3. Subroutine "dim"

This subroutine dimensions the string and array variables required by the main program. The order is important since data being stored on tape must come from a single block of machine memory. B$, C[*] and E[*] must therefore be dimensioned consecutively so they occupy a contiguous block of memory and can thus be stored.

A$ and B$ are the string variables used to store the present and past clock readings respectively. C[9,0:23] is a 9 row x 24 column array variable in which the data for a 24 hour day is stored. The columns 0 through 23 are the storage locations for the hours 00 through 23 respectively. The rows contain data as follows:

Row	Data (for the hour)
1	# of valid samples
2	# of bad samples
3	average signal power
4	median signal power
5	# 10 db fades
6	# 15 db fades
7	# 20 db fades
8	# 25 db fades
9	# 30 db fades

E[-90:-45] and A[-90:-45] are 45 element variables the elements of which serve as bins for counting the number of times the (signal power) sample value falls within the corresponding 1 dbm range. For example, any time a sample value lies within the range -53^{+} dbm to -54 dbm the value of A[-54] would be incremented by +1. The distribution is accumulated on an hourly basis in A[*] and at the end of each hour. A[*] + E[*] $\rightarrow$ E[*] and A[*] is cleared for the new hour. E[*] is cleared after being stored on tape at the end of each day. The last variable, C$[16] is used for printing headings and data using the 16 column thermal printer which is an integral part of the HP9825 controller. This variable could be eliminated if all printing is suppressed.

4. Subroutine "samp"

This subroutine commands the DVM to sample the detector output and return the sample value to the simple variable A.

If the result is 0 the process is repeated until A>0. Otherwise the input signal power in dbm is calculated from the DVM reading and is stored in A. If the input signal power is outside the range -45 to -90 dbm then the sample is considered invalid (C[2,HH] + 1 → C[2,HH]), its value is displayed and another sample is taken. If the sample is valid execution continues with a return to the main program.

Note that the RF signal power is calculated in line 50. This statement implements equation (1). However, since equation (1) is a fit to the receiver/detector calibration curve, it does not include any gain or loss between the antenna terminals and the receiver input. In line 50 as shown, a gain of 21 db has been included to account for the sum of transmission line loss and preamplifier gain. The exact value used here will of course depend upon user hardware.

5. Subroutine "sum"

This subroutine calculates the signal power in milliwatts and adds this to the sum for previous readings for the same hour. The sum is stored in C[3,HH] where HH = current hour (from A$). The valid sample count for the current hour is incremented by +1 (C[1,HH]).

6. Subroutine "bin"

The value of the count (current hour) for samples with value in the same bin as the current sample is incremented by +1. That is A[dbm] + 1 → A[dbm] where dbm = int (sample power in dbm).

7. Subroutine "fade"

This subroutine tests for negative slope crossings of thresholds at 10 db, 15 db, 20 db, 25 db and 30 db below the median signal power for the previous hour. If the current sample (A) is below the threshold and the previous sample (B) was above the test criterion is met. In this case the fade count for that threshold level for the current hour is incremented by +1. After all thresholds have been checked execution continues with a return to the main program.

8. Subroutine "avg"

This subroutine calculates the average signal power (milliwatts) and stores the result (dbm) in C[3,HH] where HH = previous hour (B$). If no valid samples were obtained the previous hour the subroutine is exited. It is executed hourly.

9. Subroutine "med"

This subroutine calculates the median signal power. The number of valid samples for the previous hour is divided by two and the number of samples in the bins of A[*] are summed until the sum exceeds half the number of valid samples. The bin for which this condition occurs corresponds to the median (to an accuracy of -0, +1 db). The median is stored in C[3,HH] where HH = previous hour (B$). Subroutine "med" also adds the hourly bin count (A[*]) to the sum for the previous hours of the same day (E[*]) and clears A[*]. The median signal power is also stored in E which is used as a reference for counting fades using subroutine "fade". Subroutine "med" is executed hourly.

10. Subroutine "hrly prt"

This subroutine labels and prints all the data in C[1,HH] through C[9,HH] at the end of each hour HH. Fade data only appears if fades occurred. A sample printout is shown in the next section. If clock (reading) errors occurred this fact is also printed. This is explained later in this section. This printout may be suppressed by deleting line 31 in the main program. No propagation data is lost as this is stored on tape. Clock errors are not stored permanently, however, and this data is lost if not printed.

11. Subroutine "clr C[ ]"

This subroutine is executed at the beginning of each new day and clears the variable C[*] for accumulation of data for the new day.

12. Subroutine "tsto"

This subroutine is executed at the beginning of each new day. It extracts the date DD for the previous day from B$ and stores B$, C[*] and E[*] in file DD on track 0. If the file contains data for the same day of a previous month then this data is overwritten. Minimum file size is 2100 bytes; B$ 12 bytes, C[*] 1728 bytes and E[*] 360 bytes.

13. Subroutine "dly prt"

This subroutine is executed at the beginning of each day. It prints the number of samples obtained for each power level during the previous day. See the sample printout in the next section. The printout may be suppressed by deleting line 34 in the main program.

14. Subroutine "rcvr"

This subroutine provides the potential for (but does not guarantee) error recovery in the event of some unforseen, previously undiscovered error of either a hardware or a software nature. It will be discussed shortly. The print statements appearing in lines 129 through 131 of this subroutine may be deleted. However, it will not be possible to determine the nature of an error or the fact that one occurred if this is done. On the other hand, if the error is recurring the machine may loop endlessly through the "rcvr" subroutine printing the same three lines each time.

C. Error Detection and Recovery

In running the program described here it was found that occasionally an inexplicable error would occur where the clock was read to A$. This caused erroneous operation of the program. The nature of the error was always the same. All clock characters were shifted one space to the left in A$ leaving only one leading space instead of two. The element A$[12] was filled with the character ←. If such an error occurred at 1345 the hour would be extracted from A$ as 34 vice 13. An attempt to then store data in column 34 of C[*] would lead to an error since this subscript is out of bounds. This is apparently a hardware error.

Several clocks were tried in the system with the same results. The error rate appeared to be about 10^{-5} to 10^{-6}. Since the clock is read each time a sample is taken and the sample rate is about 7/second, 10^5 readings are taken in a period of about four hours. Errors generally occurred anywhere from a few hours to a few days after the program was started. Evidently it was necessary to circumvent this problem.

An error detection scheme was developed as follows. A correct clock reading in A$ has two leading blanks. The first clock character is a status byte which is a space unless the clock has lost power and come back on without being reset in which case a ? is sent. The second character is always a space. All observed erroneous clock readings resulted in the loss of the second leading space. Therefore, a statement was included in the program to detect clock read errors by testing for the absence of this space. This statement appears in line 7 (bootstrap) and in line 20 of the main program (Figure 4). If an error is detected the clock is read again. In line 20 clock errors are counted. The count is set to zero at the beginning of each hour. If errors occur the number is printed by the subroutine "hrly prt".

The Advanced Programming ROM provides an error recovery statement. This statement appears in line 1 (Figure 4). When an error occurs, the program branches to the subroutine "rcvr". This subroutine causes the nature of the error to be printed and then causes the program to resume execution at line 0 after placing an abort message on the bus. If the error does not recur, then the system will recover.

The error recovery subroutine provides a potential for but does not guarantee error recovery from unforeseen error conditions. For example, if the program is loaded and a "run 1" statement is executed the program will begin execution at line 1 without having dimensioned variables (this is done in line 0). An error will then occur at line 5 since C$ is not dimensioned. The error recovery routine will allow recovery from this condition.

If no clock error detection statements were included in the program then clock errors would result. The error recovery routine would prevent the system from stopping but data would be lost. It would not prevent erroneous, non-catastrophic program operation such as data storage in an incorrect file at an incorrect time as a result of clock errors leading to incorrect but in bounds values of hours and dates.

It appears that error recovery can never be fully guaranteed since the nature of all possible errors cannot be anticipated. Only a potential for error recovery can be provided.

IV. SYSTEM OPERATION

System operation is straightforward once the necessary hardware and instruments have been assembled (Figure 1). The first step is to calibrate the receiver/detector. A curve may then be fit to the measured characteristic in a manner similar to Equation (1). Program line 50 (Figure 4) should be written to implement the equation for calculation of signal power from detector voltage. Any transmission line loss or preamplifier gain must also be taken into account.

The user may wish to make modifications to the program. A wait statement in a loop at the beginning of the program may be added to allow time for equipment warmup and stabilization. This permits unattended operation where power failures may occur. Printing may also be suppressed as discussed earlier. It would then be necessary to write a separate program or subroutine to read and process data from the tape files.

The digital clock is a critical component of the Data Acquisition and Processing Subsystem. System program decisions are made based upon the date and time. If the capability to restart after a power failure is desired then the clock must be provided with standby power. This is easily accomplished by supplying 9 volts to a rear panel connector on the clock.

A tape cassette must have the necessary files marked on track 0. File 0 should be marked for 5000 bytes. This allows room for modification and expansion of the program by the user. Files 1 through 31 should be marked at 2500 bytes length. The system program is then entered into the HP9825 from the keyboard and recorded in file 0, track 0.

The program is started manually from the keyboard or in the event of a power failure the program is loaded from tape and run automatically when the HP9825 is powered on. Once running the system needs little attention. If printing is used the controller must be kept supplied with paper. About 36 inches/day is used. If a permanent tape data record is desired then the tape should be replaced monthly, probably on the first day of each month.

Figure 6 shows sample printed output. The signal in this case was the 191.75 MHz FM sound carrier of TV9 in San Francisco. This signal was received using a log periodic dipole array in Monterey, a distance of about 125 miles.

The hourly printouts show that about 24000 samples were taken each hour (there were no invalid samples). The average signal strength varied from a maximum of -53.82 dbm at 1100 hours to a minimum of -55.97 dbm at 1900 hours. This 2 db variation is considerably less than that normally observed for this signal. However, the minimum signal strength does normally occur at sunset. It can also be seen that 5 fades of depth 10 db occurred during the period 1900 - 1959:59. These fades were 10 db relative to the median for the previous hour which was -56 dbm.

```
DAY  9/30

00 HOURS
# valid       23734
# bad             0
avg dbm      -55.08
med dbm         -56

01 HOURS
# valid       23857
# bad             0
avg dbm      -54.71
med dbm         -55

02 HOURS
# valid       23862
# bad             0
avg dbm      -54.62
med dbm         -55

03 HOURS
# valid       23861
# bad             0
avg dbm      -54.70
med dbm         -55

04 HOURS
# valid       23860
# bad             0
avg dbm      -54.92
med dbm         -55
#10db fades       1

05 HOURS
# valid       23855
# bad             0
avg dbm      -55.15
med dbm         -56

06 HOURS
# valid       23855
# bad             0
avg dbm      -55.22
med dbm         -55

07 HOURS
# valid       23857
# bad             0
avg dbm      -54.86
med dbm         -55

08 HOURS
# valid       23857
# bad             0
avg dbm      -54.13
med dbm         -55

09 HOURS
# valid       23861
# bad             0
avg dbm      -53.85
med dbm         -54

10 HOURS
# valid       23862
# bad             0
avg dbm      -53.92
med dbm         -54

11 HOURS
# valid       23859
# bad             0
avg dbm      -53.82
med dbm         -54

12 HOURS
# valid       23854
# bad             0
avg dbm      -54.72
med dbm         -55

13 HOURS
# valid       23847
# bad             0
avg dbm      -54.32
med dbm         -55

14 HOURS
# valid       238
# bad
avg dbm      -54.5
med dbm         -5

15 HOURS
# valid       238
# bad
avg dbm      -55.
med dbm         -5

16 HOURS
# valid       2385
# bad
avg dbm      -55.2
med dbm         -5

17 HOURS
# valid       2385
# bad
avg dbm      -55.
med dbm         -5

18 HOURS
# valid       2384
# bad
avg dbm      -55.
med dbm         -5
```

FIGURE 6. System Program Sample Output For One 24 Hour Day

19 HOURS	
# valid	23859
# bad	0
avg dbm	-55.97
med dbm	-56
#10db fades	5

20 HOURS	
# valid	23857
# bad	0
avg dbm	-55.75
med dbm	-56

21 HOURS	
# valid	23857
# bad	0
avg dbm	-55.28
med dbm	-56

22 HOURS	
# valid	23861
# bad	0
avg dbm	-54.99
med dbm	-55

23 HOURS	
# valid	23862
# bad	0
avg dbm	-54.94
med dbm	-55

DAILY
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SIG PWR	#SAMPLES
-50 dbm	0
-51 dbm	0
-52 dbm	0
-53 dbm	8
-54 dbm	63777
-55 dbm	267531
-56 dbm	215156
-57 dbm	25802
-58 dbm	82
-59 dbm	18
-60 dbm	9
-61 dbm	4
-62 dbm	6
-63 dbm	3
-64 dbm	6
-65 dbm	2
-66 dbm	17
-67 dbm	18
-68 dbm	1
-69 dbm	0
-70 dbm	0
-71 dbm	0
-72 dbm	0
-73 dbm	0
-74 dbm	0
-75 dbm	0
-76 dbm	0
-77 dbm	0
-78 dbm	0
-79 dbm	0
-80 dbm	0
-81 dbm	0
-82 dbm	0
-83 dbm	0
-84 dbm	0
-85 dbm	0
-86 dbm	0
-87 dbm	0
-88 dbm	0
-89 dbm	0
[illegible]	[illegible]

FIGURE 6. System Program Sample Output
For One 24 Hour Day
(Continued)

The daily distribution of signal samples appears following the printout for 23 hours. This shows most samples in the -55 dbm bin (-54.01 dbm to -55 dbm) with the highest signal strength measured as -52.xx dbm. The 18 samples in the -67 dbm bin and the 1 sample in the -68 dbm bin occurred during the 5 fades in the 1900 hour period. It is clear a number of fades of depth less than 10 db also occurred during the day.

The average duration of the 10 db fades may be calculated. For the 1900 hour period we have

$$\bar{t}d = \frac{19 \text{ samples}}{5 \text{ fades}} \times \frac{3600 \text{ sec}}{23859 \text{ samples}} = .57 \text{ sec}$$

In this expression, 19 is the number of samples faded below 10 db (from daily distribution) and 5 is the number of such fades. The number of samples taken during the 1900 hour period is 23859 and this is a 3600 second interval.

In some applications it might be of interest to know the distribution of fade durations. The system as configured does not provide the capability to acquire this data. Such a capability could probably be added to the system, however.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The Radiowave Propagation Data Acquisition System described here utilizes commercially available hardware and may be easily implemented by other investigators using the system program described in this report. The system samples the signal at a rate of about 7 samples/second and computes signal power for each sample. Average and median signal power is calculated for each hour of the day and fades of depth 10 db to 30 db relative to the median for the previous hour are counted. A daily distribution of signal power is generated and all processed data are stored on tape once each day. Tape files hold data for up to 31 days.

This system has provided reliable and trouble free operation throughout several months of testing.

B. Recommendations

This system has the capability to run unattended. In some applications it may be of interest to obtain data at locations that are unmanned and not easily accessible. It may then be necessary to consider transmission of data to a remote receiver such as another HP9825 calculator.

It is recommended that the system be configured in the future to permit remote data acquisition.

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